Journal of Information Systems Engineering and Management
2025, 10(17s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Process Management Maturity

Herbert Ricardo Garcia Viana[1], Roni Neon Sousa Freire[2*], Gustavo Lopes da Silva[3]

[1] *Department of Production Engineering, Federal University of Rio Grande do Norte - UFRN, Natal, Brazil*

[2] *Department of Process and Project, Paragominas Mining - MPSA, Paragominas, Brazil*

[3] *Department of Process and Project, Paragominas Mining - MPSA, Paragominas, Brazil*

**Corresponding Author: gustavo.lopes@hydro.com*

ARTICLE INFO

Received: 10 Dec 2024

Revised: 29 Jan 2025

Accepted: 11 Feb 2025

ABSTRACT

The excellence in maintenance is closely linked to an organization's ability to ensure safety, performance, adequate costs, and reliability of its assets. Achieving maintenance excellence requires the adoption of effective management practices that elevate the maturity level of processes. This study explores a model for evaluating maintenance management maturity, focusing on Mineração Paragominas (MPSA), a bauxite mining company. Information collection allowed for an analysis of current practices compared to 367 requirements outlined in maintenance checklists (roadmaps) for mobile equipment in mining and industrial maintenance, identifying gaps to achieve maintenance excellence. It was necessary to implement a model to assess the maturity level of maintenance management in the organization, aiming to promote continuous improvement among all involved in maintenance activities. The maintenance excellence evaluation model served as a tool to measure the maturity level of maintenance management at MPSA, showing an improvement of 9.3 percentage points between 2022 and 2024, corresponding to the first and second diagnostic cycles, respectively.

Keywords: Asset Management, Maintenance, Maturity, Process.

INTRODUCTION

For Viana & Ribeiro (2017), the increase in production, combined with technological advances, has made industrial parks more susceptible to the need for maintenance. The Maintenance Function, being a strategic function in organizations, plays a crucial role in ensuring the availability of assets and exerts a significant influence on the company's results.

In terms of maturity in the Maintenance Function process, Viana (2021, p. 85) states that "the search for the perception of maturity of processes in the various fields of activity of an organization has been a point of relevant importance in business management". An evaluation model that verifies the maturity of the application of the Maintenance Function processes consists of a relevant checking tool for companies and their results, which makes them able to identify and propose changes with the objective of improving their management processes. In the Maintenance Function, several maturity levels have been presented over the years by researchers, some of which are presented in the literature review of this article. This effort aims to find a maturity index in maintenance, capable of indicating, with adequate foundation, the stages of maturity in which an organization is in relation to its practiced process management.

The assessment of process maturity involves the application of a diagnosis, similar to a certification audit. For ISO 19011 (2018), an audit consists of a systematic, independent and documented process to obtain objective evidence and evaluate it objectively, to determine the extent to which the audit criteria are met. In the “Audit”, the auditors

are external, usually from a certifying entity, and the reference model adopted are standards such as ISO 9001, 14001 and 55001, among others. It is clear that the focus of the audit consists of measuring a model, exploring guidelines defined in the standard, and seeking to understand how the audited company meets such guidelines, and whether this compliance is effective. In the "Diagnosis" process, the diagnosticians are internal and can count on the support of consultants throughout the process. Generally, the formation of groups of evaluators in a cross-disciplinary manner is adopted, where professionals from one department evaluate another. This aims to strengthen mutual learning and provide new perspectives on the diagnosed processes, allowing leadership to make better decisions. Considering that leadership is a success factor for all organizations (Viana, 2018), the importance of the diagnostic process is clear.

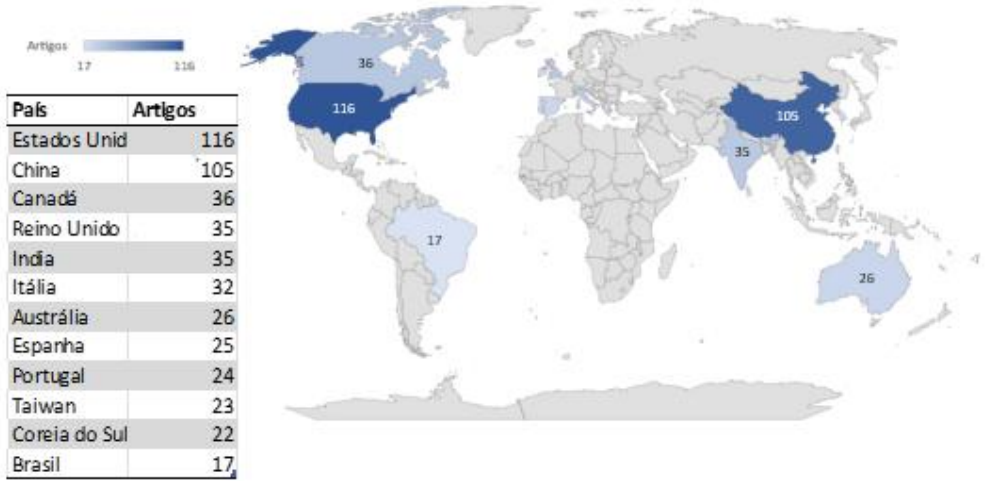
In light of this discussion, the research question arises: "How can we assess the maturity of the Maintenance Function in a bauxite mining company?"

The main objective of this work is to propose a model for assessing the maturity of the Maintenance Function in a mining company. The specific objectives include: (i) Investigating and studying maturity measurement models found in the literature; (ii) Developing a diagnostic model to assess the maturity of Maintenance Function processes in a mining company; (iii) Applying the developed model to a practical case.

The research on this topic is justified by Viana's (2020, p. 43) statement that "adequate Asset Management necessarily involves well-articulated and competent Maintenance Management", thus highlighting the strategic importance of the Maintenance Function in high-investment operations.

In addition, academic research on the topic of "maintenance management system" presents opportunities for contributions. Note Figure 1, which shows the scientific production of articles between 2013 and 2023 in 12 countries with the highest academic production, published in the Scopus database, with the following combination of keywords: "management system" and "maintenance".

It can be seen that of the 12 (twelve) countries that presented the most scientific works in the world in the Scopus database, Brazil is in 12th place with the production of 17 articles, which particularly denotes a gap in national studies, given the importance of the topic for the Brazilian economy and production, which justifies the research presented in this work.



País	Artigos
Estados Unid	116
China	105
Canadá	36
Reino Unido	35
India	35
Itália	32
Austrália	26
Espanha	25
Portugal	24
Taiwan	23
Coreia do Sul	22
Brasil	17

Figure 1. Production of articles in the Scopus database by country with the keywords: "management system" and "maintenance" between 2013-2023.

The effort to analyze managerial maturity in the Maintenance Function is centered on the search for the truth of the facts. As highlighted by Viana & Xavier (2024), this represents one of the most complex challenges for human thought, since the relevant question may not be "what is the truth?", but rather "whose is the truth?". In capital-

intensive organizations, the lack of a standardized management system that is logically interconnected with its processes can be detrimental, as it allows each manager to establish their own "truth", resulting in diffuse management models.

The choice of applying the work to the mining sector is justified by the understanding of Viana & Xavier (2018, p. 792), when they argue that "from the 18th century to the present day, mining has occupied a prominent place in the Brazilian economy, reverberating its influence on education, science, technology, culture and employment".

.

THEORETICAL FRAME OF REFERENCE

The theoretical framework in a study comprises a critical and organized analysis of the literature relevant to the topic, providing a theoretical contextualization and defining the key concepts. It should comprehensively contain the theories, models and previous research, identifying gaps, contradictions and consensus in the literature that are important for the focus of the work being developed.

Maintenance and Audit Management

The word Maintenance comes from the Latin term, manus tenere, which means “Keep what you have in hand”, as explained by Ferraz Júnior (2009).

The maintenance area has gained the status of a strategic function due to its current role in production systems, where it relies on its good performance, the availability of assets and their due calibrations (VIANA, 2020). This fact contributes to ensuring the intrinsic quality of products, with maintenance being an active and important participant in the strategy of organizations (Nascif; Kardec, 2001; Viana et al, 2018).

Viana (2024) presents a management system for maintenance processes, entitled by the author as the “CIT/CSM Model”. It can be seen in Figure 2 that in the macroprocess proposed by the author, the “Maintenance Control” process foresees the activity of “Internal audit of maintenance processes”, which for Viana (2021, p.80), represents:

“The ‘Internal Audit of Maintenance Processes’ consists of a detailed examination of the good practices carried out by the maintenance team, identifying the procedures adopted, verifying their reliability, thus verifying the adherence of the maintenance teams to the Maintenance Function procedures, such as the process activities provided for in their standardized protocols for each requirement of the maintenance management system designed in the macro process.”

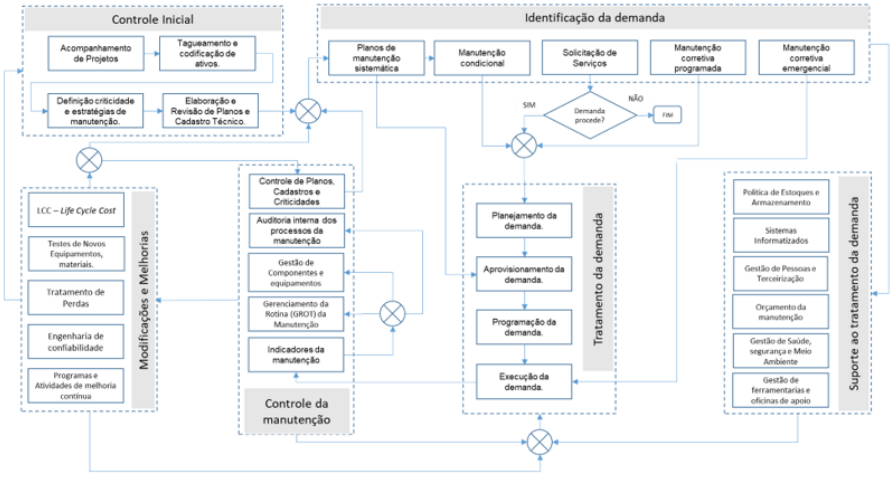


Figure 2. CIT/CSM model

Maintenance and Audit Management

Audits aim to attest to the level of maturity of organizations in their management systems. In terms of maintenance, there are several studies in this line. ISO 9004 (2010) defines maturity as sustained success, which is achieved when the organization meets the needs and expectations of all interested parties (stakeholders), in the long term and in a balanced manner.

Viana (2020) presents a literature review on the approach to the concept of maturity in the Maintenance Function. The author compiles in Table 1 the view of each author researched regarding the levels of maturity in maintenance management.

Table 1. Maturity Levels by authors researched by Viana

Autores	Nível de Maturidade I	Nível de Maturidade II	Nível de Maturidade III	Nível de Maturidade IV	Nível de Maturidade V
Wireman (1992)	Incerteza	Despertar	Esclarecimento	Sabedoria	Certeza
Cholasuke et al. (2004)	Inocência	Entendimento	Excelência	-	-
Jamarillo (2004)	Manutenção Planejada	Manutenção Pró-ativa	Manutenção Organizacional	Gestão de Confiabilidade	Gestão de Ativos
Campbell e Reyes-Picknell (2006)	Inocência	Consciência	Entendimento	Competência	Excelência
Macchi e Fumagalli (2013)	Inicial	Administrado	Definido	Administrado Quantitativamente	Otimizado
Viana	Inocência	Construção	Consciência	Evolução Sustentável	Excelência

It is noted that the last line of Table 1 represents VIANA's (2021) contribution to the discussion on the topic of maturity in maintenance management, indicating that there are 5 (five) maturity levels, based on the macro process of the CIT/CSM model (Figure 1).

The levels of maturity in maintenance management, according to the author, are as follows:

a) Innocence;
b) Construction;
c) Consciousness;
d) Sustainable Evolution;
e) Excellence.

MATERIALS AND METHODS

Regarding the nature of the research, according to Turrioni and Melo (2012), this work is considered as applied research, as it generates knowledge for practical application, directing the solution of specific problems. Regarding the objective, the research can be classified as exploratory, descriptive and explanatory. The research in question is characterized as exploratory, as it aims to bring the problem closer to the community and society.

Regarding the approach, research can be classified as qualitative or quantitative. The study in question is characterized as qualitative, due to its in-depth understanding of a certain problem of a given social group.

To develop research, it is essential to select the research method to be used. This research is applied in nature, with an exploratory objective, using a qualitative approach and bibliography and field research as methodology, as shown in Figure 3.

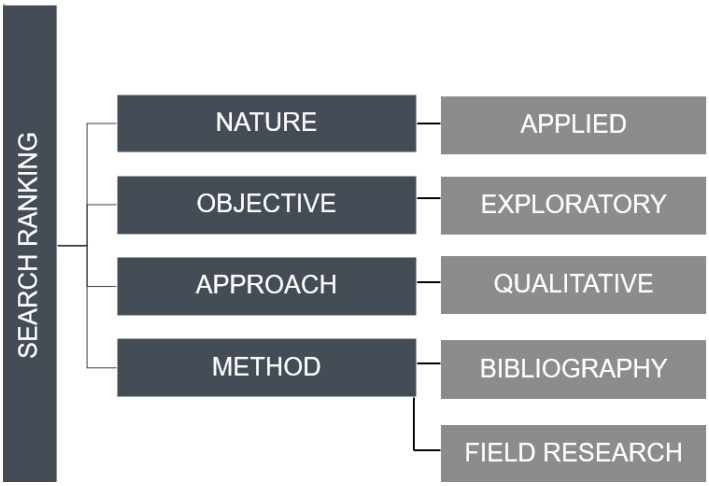


Figure 3. Search Classification

Figure 4 presents a summary of the stages of the model developed and applied to assess the maturity of the Maintenance Function processes in a bauxite mining company. The eighth stage highlights the applied nature of the work, as it focuses on the generation of knowledge that will later be applied in a practical way to solve certain problems (Silva et al., 2024).

Figure 4. Stages of preparation and application of the Maintenance maturity assessment model

The steps were applied in a 1st diagnostic cycle carried out in 2024, as well as in the 2nd cycle applied in 2024.

Diagnostic scope and roadmaps

The scope of the maintenance diagnosis included the audit of 11 processes (Figure 5), being applied in two large areas of the company, industrial maintenance and maintenance of mobile mine equipment.

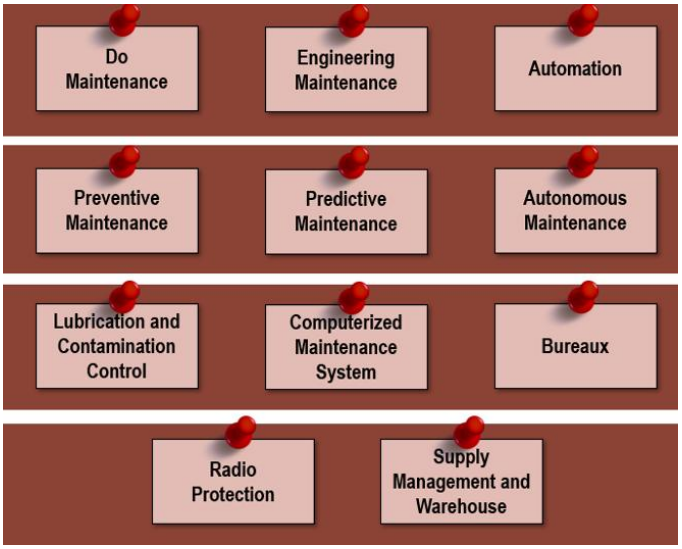


Figure 5. The 11 (eleven) audited processes

For each process in Figure 5, questions were developed in the diagnostic checklists (Roadmap) based on the triggers of the procedures and processes of the routines to be diagnosed.

The MPSA roadmaps gathered 184 questions applied to Mine Maintenance (Mobile Equipment), and 183 questions applied to Industrial Maintenance, with a total of 367 questions to evaluate the 11 checklists as shown in Figure 1.

The practice of adopting an objective and clear description for each level of adherence is quite favorable for a productive and educational diagnosis, which increases the chances of detecting gaps, as well as good practices in the Maintenance Function, thus generating pertinent and effective actions in plans to improve the Management System. In this way, the roadmaps had a clear and objective description for each item, for its fulfillment at the different levels of adherence, as illustrated in Figure 6.

0	1	3	5
Não realiza ou Não encontrado Evidências	A área possui padrão publicado acerca das análises que devem ser realizadas em novos projetos.	A área atende ao item anterior, bem como, evidencia estudos para atendimento aos requisitos legais dos novos projetos.	A área atende ao item anterior, bem como, apresenta análises de confiabilidade (RAM) e de custos de vida (LCC) para os novos projetos, quando necessário.
Não realiza ou Não encontrado Evidências	A área atende aos seguintes critérios para todos os novos ativos: • Definiu a regra de criação estrutura de taxonomia e locais de instalação. • Elaborou os planos de manutenção.	A área atende ao item anterior, bem como, Elaborou Cadastro de todos os itens lista técnica no SAP, para todos os novos ativos.	A área atende ao item anterior, bem como, Analisou lista preliminar de sobressalente criticados conforme politica, estimativa de OPEX e mão de obra necessária de manutenção, operação e apoio para todos os novos ativos.
Não realiza ou Não encontrado Evidências	A área definiu a criticidade dos novos ativos conforme método definido pela Mineração Paragominas.	A área atende o item anterior, bem como, apresenta correto cadastro de objetos técnicos no SAP dos novos ativos.	A área atende ao item anterior, bem como, está em linha com os planos de treinamento das áreas e de sobressalentes para os novos ativos.

Figure 6. Part of the Roadmap with a description of service at levels 0, 1, 3 and 5.

Sample calculation

Once the questions for the diagnostic roadmap and their respective triggers had been defined, it was necessary to define the sample size for each trigger so that the audit could statistically represent the population to be studied.

The concept of a diagnostic trigger is the guidance given to the diagnostician that will lead him to the smallest auditable unit of a process (an OM, a Technical Note, an indicator, etc.).

Situations were presented in which objective evidence was obtained through sampling of the population, such as evidence involving Maintenance Orders (OMs). For this purpose, the calculation predicting the "expected proportion" was used according to equation 1.

$$n = \frac{p.(1-p).Z^2.N}{\varepsilon^2.(N-1)+Z^2.p.(1-p)} \qquad (1)$$

Where:

p: Expected proportion (p), represents what is expected to be found in terms of compliance, based on literature indications;

ε: Estimation error (ε), represents the level of error that can occur in the estimate;

Z: Value of the normal distribution for a stipulated reliability level (Z), consists of a tabulated value, as per table 4;

N: Population Size;

Figure 7 indicates the value of the normal distribution for a reliability level (Z), adopted at a reliability level of 90%, which balances the number of samples, with a good level of reliabilliity, since populations of high values were expected when dealing with transactions generated in a company of the size of MPSA.

Nível de Confiança	90%	91%	92%	93%	94%	95%	96%	97%	98%	99%
Z	1,65	1,70	1,75	1,81	1,88	1,96	2,05	2,17	2,33	2,58

Figure 7. Reliability level

Levels of compliance with roadmap and maturity requirements

The requirements set out in the roadmap present different levels of service, therefore, levels and guidelines for these were defined as shown in Figure 8.

PERFORMANCE	Level of Service	Checklist Questions	Score
	Doesn't accomplieshed	It is not possible to answer the question with tangible evidence	0
	Partially accomplieshed	It is possible to answer the question with tangible evidence, but it is insufficient (not everyone complies, or steps are omitted by everyone) or conflicting. (each person works in a different way)	1
	Accomplieshed	It is possible to answer the question with tangible evidence, without reservation.	3
	Reference	The evidence obtained exceeds the requirements, generating opportunities for internal benchmarking.	5

Figure 8. Levels of Compliance with the Questions in the Answer Sheet (Checklist)

The score obtained was converted into a percentage, according to the relationship between points obtained versus total points, observing the lenses by process and area. For the purposes of summing the scores, level "1" corresponded to "1.5" points, that is, 30% of the maximum score of "5", and level "3" corresponded to "3.5" points, equivalent to 70% of the maximum score.

Five levels were adopted to represent maturity, according to Viana (2021), namely: (i) Innocence; (ii) Construction; (iii) Consciousness; Sustainable Evolution and (v) Excellence. The score for each maturity level was detailed as shown in Figure 9.

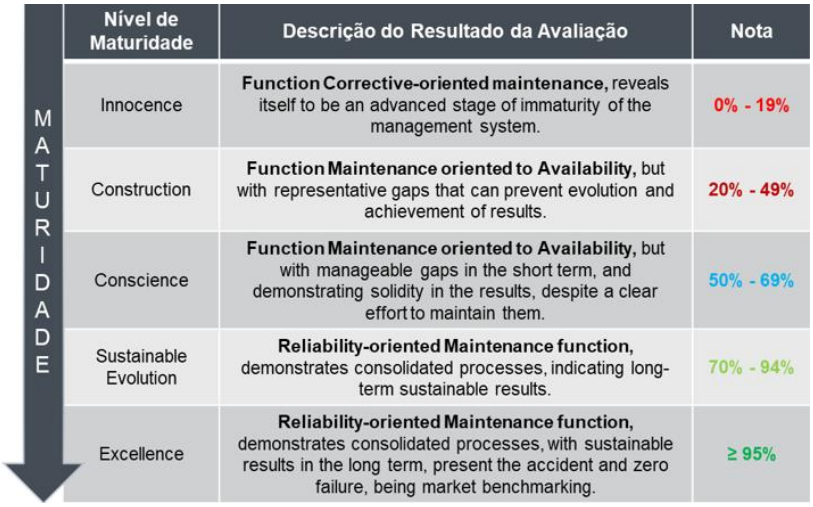


Figure 9. Maturity levels for Maintenance Function Diagnosis

Coordination of the Diagnostic Program

The responsibility for coordinating the audit program fell to the Management System Management, establishing the planning and management of the diagnostic program, with the following responsibilities:

a) establish, implement, monitor, critically analyze and improve the diagnostic program;

b) identify the necessary resources and ensure that they are provided.

The diagnostic standard was guided by field practice based on the guidelines of the ISO 19011 standard, which guides the assessment of management systems, for a uniform approach to the audit process in which multiple systems are implemented and maintained.

During the audit, non-conformities or failures to meet the mapped requirements were recorded to contribute to the construction of the final action plan.

Expected behavior for diagnosticians

The expected behavior of the diagnostician, who must have the necessary skills, is a crucial factor. In addition, other principles are related to it, which are by definition independent and systematic. The following principles are related to diagnosticians, as per guidance provided in the NBR ISO 19011 standard:

a) Ethical conduct: is the foundation of professionalism, where trust, integrity, confidentiality and discretion are essential elements for conducting the audit.

b) Fair presentation: implies the obligation to report the results of the audit accurately and precisely.

c) Due professional care: requires the application of diligence and judgment in conducting the audit.

d) Independence: is the basis for the impartiality of the diagnosis and the objectivity of the conclusions.

e) Evidence-based approach: constitutes the rational method for reaching reliable and reproducible conclusions in a systematic audit process.

APPLICATION OF DIAGNOSIS AT MPSA

After preparing the audit program and the 11 roadmaps, the first in-person diagnostic cycle was carried out at Mineração Paragominas, in periods distributed in the months of August, September, and October 2022. There were 36 interviews involving several professionals from Mine Maintenance and Industrial Maintenance, as well as the areas of Supplies, Warehouse, Contract Management, and Operations. More than 100 hours were dedicated to such meetings and visits to the area (Figure 10).

In the first quarter of 2024, the second diagnostic cycle was conducted, with the aim of verifying the developments resulting from the actions implemented based on the improvement observations identified in the first cycle. These

observations led to the preparation of an action plan in the areas, aiming at adapting to the best market practices for the Maintenance Function processes.

Figure 10. Illustration of the first diagnostic cycle carried out in 2022

The evidence obtained in the interviews, both in the first and second cycles, fed into the 11 roadmaps for mine and industry maintenance, revealing different levels of maturity between the processes. This highlighted gaps, as well as identified good practices. All the requirements assessed were discussed and recommendations were made to develop an action plan aimed at sustaining and continuously improving the assessed processes, as exemplified in Figure 11.

Quesito 1.07 - A priorização de execução das OM´s adota métricas pré-estabelecidas pela a área, considerando regras claras de sequência de OM´s a serem realizadas, e o cumprimento pela área de tais métricas é efetivo?

Nível Atingido: 3,0 (Satisfatório).

Comentário: A área está elaborando matriz de priorização de OM´s, levando em conta a criticidade, o nível de urgência do serviço, o perfil de perdas e HSE, o objetivo da área é gerar um script automático para geração da carteira priorizada, conforme Evidência 6. Enquanto isto, A priorização é feita pelo Executante/PCM. Item 10.4.1.3 do MDM, revisar o MDM pois o mesmo não traz as prioridades de 1 a 7.

Figure 11. Excerpt from a question discussed in the diagnostic report

It is worth noting that the objective of this study was not to compare the performance of MPSA's maintenance maturity with that of other companies, but rather to compare its own results year after year, assessing the increase in the level of maturity over time. The results obtained by applying the 11 roadmaps classified the processes are presented in Table 2.

Table 2. Result of the Maintenance Function Diagnosis by process in 2022 (1st Cycle) and 2024 (2nd Cycle).

Process	Area	Result
Perform Maintenance	Mine 1º Cicle	50,7%
	Mine 2º Cicle	59,3%
	Plant 1º Cicle	54,1%

	Plant 2º Cicle	64,1%
Maintenance Engineering	Mine 1º Cicle	49,3%
	Mine 2º Cicle	58,8%
	Plant 1º Cicle	50,0%
	Plant 2º Cicle	59,0%
Predictive Maintenance	Mine 1º Cicle	20,0%
	Mine 2º Cicle	52,1%
	Plant 1º Cicle	53,6%
	Plant 2º Cicle	72,9%
Lubrication	Mine 1º Cicle	51,0%
	Mine 2º Cicle	71,0%
	Plant 1º Cicle	45,5%
	Plant 2º Cicle	66,5%
Maintenance Software	Mine 1º Cicle	48,3%
	Mine 2º Cicle	42,5%
	Plant 1º Cicle	53,3%
	Plant 2º Cicle	61,7%
Preventive maintenance	Mine 1º Cicle	60,6%
	Mine 2º Cicle	66,3%
	Plant 1º Cicle	69,4%
	Plant 2º Cicle	79,4%
Workshops/Tooling	Mine 1º Cicle	55,5%
	Mine 2º Cicle	73,6%
	Plant 1º Cicle	52,7%
	Plant 2º Cicle	64,5%
Automation	Mine 1º Cicle	72,7%
	Mine 2º Cicle	76,4%
	Plant 1º Cicle	77,0%
	Plant 2º Cicle	81,0%

Autonomous Maintenance	Mine 1º Cicle	30,0%
	Mine 2º Cicle	30,0%
	Plant 1º Cicle	32,9%
	Plant 2º Cicle	32,9%
Radioprotection	Mine/Plant 1º Cicle	95,4%
	Mine/Plant 2º Cicle	93,1%
Supplies/Warehouse	Mine/Plant 1º Cicle	76,1%
	Mine/Plant 2º Cicle	78,5%

When analyzing the results by maintenance areas (as shown in Table 3) and consolidated by MPSA as a whole, an evolution of the organization of 9.3 percentage points can be observed between the first and second cycles. This demonstrates a significant advance in the maturity of the Maintenance Function processes.

Table 3. Diagnostic Result of the Maintenance Function by area in 2022 (1st Cycle) and 2024 (2nd Cycle)

Area	Result
Mine 1º Cicle	54,6%
Mine 2º Cicle	63,9%
Plant 1º Cicle	58,4%
Plant 2º Cicle	67,9%
MPSA 1º Cicle	56,6%
MPSA 2º Cicle	65,9%

CONCLUSION

The general objective of this work was to develop and apply a model to assess the maturity of the Maintenance Function management processes in a mining company, as evidenced in sections “Diagnostic scope and roadmaps” to “Expected behavior for diagnosticians”. Based on the results of the diagnosis, it was possible to identify opportunities for improvement in each mine and plant maintenance process, in addition to proposing recommendations to align the processes with the adopted model and the criteria of each roadmap.

The recommendations were used to develop a plan with more than 200 actions at the end of the diagnosis in the first cycle carried out in 2022, prepared by those responsible for each process, with the aim of increasing maturity in the next diagnosis cycle.

Based on this plan, the MPSA score increased from 56.6% to 65.9% between the first diagnostic cycle in 2022 and the second cycle carried out in 2024, representing an increase of 9.3 percentage points. This demonstrates a significant improvement in the maturity level of the Maintenance Function processes throughout the organization.

REFERENCES

[1] Ferraz Junior, J. E., Mapping of performance perceptions of maintenance management of building air conditioning systems – The case of INMETRO. Dissertation presented to the master's program of the Fluminense Federal University (UFF), 2009.

[2] Kardec, A.; Nascif, J., Strategic Function Maintenance. Rio de Janeiro: Editora Qualitymark, 2001.
[3] NBR ISO 19011. Guidelines for quality and/or environmental management system audits, 2018.
[4] NBR ISO 9004. Quality Management, 2018.
[5] Silva, F. H. dos S., Carlos, M. do N., Costa, L. de A., Oliveira, N. A. C., & Viana, H. R. G. (2024). Strategy and maintenance plans: application of the Viana method in a wholesale and retail company from Rio Grande do Norte. FOCO Magazine, 17(3), e4639. https://doi.org/10.54751/revistafoco.v17n3-078, 2024.
[6] Turrioni, J. B.; Mello, C. H. P. Research methodology in production engineering: strategies, methods and techniques for conducting quantitative and qualitative research. 2012. Postgraduate Program in Production Engineering, Federal University of Itajubá, Itajubá, 2012.
[7] Viana, H.R.G. 7000 days of leadership. New York: University of Chicago Press, 2018.
[8] Viana, H.R.G. Maintenance Management Manual Volume 1. Brasília: Editora Engeteles, 2020.
[9] Viana, H.R.G. Maintenance Management Manual Volume 2. Brasília: Editora Engeteles, 2020.
[10] Viana, H.R.G. Maintenance Management and Engineering Course. Natal: Editora Insigne Acadêmica, 2024.
[11] Viana, H. R. G.; Ribeiro, J. L. D. Preparation and application of a maintenance master plan in a mining company. Industrial Management Journal, Federal Technological University of Paraná-UTFPR, Ponta Grossa, v. 13, n. 3, p. 37-56, Sep./Nov. 2017.
[12] Viana, H. R. G.; Marques, A.; Birani, S.; Sena, S.; Nobumasa, G. H. Reliability-centered maintenance: application in gear motors of belt conveyors in an alumina refinery. Industrial Management Journal, Federal Technological University of Paraná-UTFPR, Ponta Grossa, v. 14, n. 2, p. 186-205, Apr./Jun. 2018.
[13] Viana, H. R. G., & Xavier, Y. M. de A. (2024). Truth, conjecture and rhetoric: a reflection on a successful constitutional state. Educational and Development Journals, 16(2), e3502. https://doi.org/10.55905/cuadv16n2-119. 2024.
[14] Viana, H. R. G., & Xavier, Y. M. de A. (2024). The constitutional evolution of property rights over mineral resources in Brazil. Contributions to social sciences, 17(1), 790–813. https://doi.org/10.55905/revconv.17n.1-046. 2024